This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

AWM
W5833

G. M. WHITE

THE BEHAVIOR OF BROOK TROUT EMBRYOS FROM THE TIME OF HATCHING TO THE ABSORPTION OF THE YOLK SAC

Library
of the
University of Wisconsin

N59G5

THE BEHAVIOR OF BROOK TROUT EMBRYOS FROM THE TIME OF HATCHING TO THE ABSORPTION OF THE YOLK SAC

by

GERTRUDE MAREAN WHITE

A Thesis Submitted for the Degree of
MASTER OF ARTS

UNIVERSITY OF WISCONSIN
1914

399533
OCT 18 1933
AWM
.W5833

THE BEHAVIOR OF BROOK TROUT EMBRYOS FROM THE TIME OF HATCHING TO THE ABSORPTION OF THE YOLK SAC

by

Gertrude M. White.

CONTENTS

A. INTRODUCTION -
B. EXPERIMENTS AND OBSERVATIONS - - - - - - - - - - - - -
    1. Hatching - - - - - - - - - - - - - - - -
    2. Swimming movements - - - - - - - - - - -
    3. Reactions to mechanical jars - - - - - -
    4. Reactions to touch - - - - - - - - - - -
    5. Reactions to current - - - - - - - - - -
    6. Reactions to light - - - - - - - - - - -
    7. Reactions to current and light - - - - -
    8. Carbon Dioxide and light - - - - - - - -
    9. Reactions to shadows - - - - - - - - - -
    10. Feeding reactions - - - - - - - - - - - -
C. GENERAL DESCRIPTION OF THE EARLY LIFE OF THE BROOK TROUT - - - - - - - - - - - - - - - - -
D. SUMMARY -
E. BIBLIOGRAPHY -

A. INTRODUCTION.

Although certain senses of mature fishes have been carefully studied, little work has been done upon the reactions of embryos. The investigations of the adult fish have been made chiefly with reference to the senses of smell, taste, sight, and hearing. Herrick ('03) found that some fishes possess taste buds located in the skin, by which they habitually discover their food, while other fishes have the sense of taste confined to the mouth. That the catfish has a true olfactory sense, which is distinct from gustatory, was shown by Parker ('10). The sense of hearing has also been studied by Parker ('05, '08, '11), who believes that some fishes are stimulated by sounds of slow vibration. Bernoulli ('10), on the other hand, maintains that the fishes with which he worked do not hear, but respond through tactual and visual stimulation, when at all, to the mechanical motion of the water.

The work of Paton ('07), who describes some of the reactions of fish embryos, is of particular interest. He believes that the early attempts of fish embryos to lie upon the ventral side are not due to the influence of the nervous system, but rather to the position in which they lie in the egg, and the shape of the body, combined with the propulsion of the water. Even embryos of thirteen and fourteen millimeters show a tendency to right themselves when they swim.

This author found that trout embryos of fifteen millimeters often swam once or twice around a dish five centimeters in

diameter, but in all fishes progression was possible long before this, even at nine or ten millimeters. Squeezing or pricking the yolk sac of the trout caused exaggerated movements in the young fish. The head was found to be less sensitive to touch than the body; the eye in all stages examined was rather insensitive to touch. Prompt and unmistakable responses to thermal stimuli appeared at an early age. The rate of the heart beat at ten millimeters was twenty-five or twenty-eight, and at fifteen millimeters was seventy-five or eighty.

Since the information concerning the reactions of fish embryos is so meagre, it seems desirable that the kinds of stimulation to which various types of fish react, and the age at which such reactions begin, should be ascertained and possible applications to economic problems considered. The present paper is an attempt to give a connected account of the life activities of the Brook Trout, Salvelinus fontinalis, from the time of hatching to the absorption of the yolk sac.

The Brook Trout is usually found in clear cold spring water, and prefers brooks or streams flowing over gravelly bottoms. It pushes from the rivers into the smaller streams, seeking the head-waters, where it rests in the deep pools and eddies. Under natural conditions it is seldom found in water over 60° F. to 65° F. The Brook Trout spawns in autumn as the temperature of the water falls. The season, which usually lasts about two months, begins earlier in the northern latitudes, in the Lake Superior region in September, or even in August, while

in New York, New England, and Lower Michigan, it commences about the middle of October. The time necessary for developing the eggs is dependent upon the temperature of the water, varying from about 125 days at 37° F. to about 50 days at 50° F.

The experiments here described were performed in the Zoological Laboratories of the University of Wisconsin. About five hundred embryos were used, eggs being obtained at the Madison Fish Hatchery, and brought to the laboratory in four different batches, so that embryos of various stages could be observed at the same time. The youngest stages were kept in a wire tray in a trough of running water (from Lake Mendota) while the older individuals were placed in glass dishes and set in running water to keep them cool. About one hundred Rainbow Trout, *Salmo irideus*, of two different stages and a number of young German Brown Trout, *Salmo fario*, which swam freely in the trough, were kept under observation.

During the experiments the temperature of the water ranged from 5° C. to 10° C. Most of the experiments were performed in a dark room, the temperature of which was usually about 19° to 21° C. The fish were handled with a feather or with a spoon made of bent wire with netting stretched across it. Although there was a high rate of mortality (due to gas-bubble disease, fungi, algae which crept into the gills, and persistant handling), several of the Brook Trout survived during the whole period. All experimental data refer to the Brook Trout unless otherwise stated.

B. EXPERIMENTS AND OBSERVATIONS.

1. Hatching.

The egg of the Brook Trout is small and nearly colorless, measuring about four millimeters in diameter. The embryo, which is about three times as long as the diameter of the egg, lies curled around its yolk sac with the tip of the tail beside the head. The eyes and head are visible through the thin shell. The hatching is initiated by movements starting at the head and later extending through the whole length of the body, so that the position of the embryo in the egg is somewhat changed. Such movements continue at intervals, varying from a quarter of a minute to an hour or more, until the shell is so strained that a slit appears. There does not seem to be any distinction as to which part of the embryo comes out first, for in the twenty-three cases observed, eight embryos appeared head first, one tail first, and in fourteen cases, the yolk sac broke through before the body. The final shedding of the egg case is sometimes brought about by a violent movement of the body, but in nearly all the instances observed, it was a gradual process lasting from three quarters of an hour to five or six hours, during which the initial slit was slowly enlarged by the rhymical motions of the body and the respiratory movements. If the anterior end is

to be the first to appear, the violent contraction of the embryo raises the head until the strain splits the shell far enough to free the region bearing the pectoral fins, which immediately begin to move. The front of the head soon follows. Whether the tail or the yolk sac comes out first, the length of time required is nearly the same, and the details of the process differ very little. Unless the animal is disturbed, it may lie quiet for hours while the egg case slips off, but if the fish is jarred, a violent contration almost invariably results, thus hastening the loss of the egg case. In nature where there are great numbers of fish hatching simultaneously, they undoubtedly touch one another continually, shortening the time required for hatching.

The Brook Trout makes its appearance as a pretty, delicate, translucent creature about twelve centimeters long. Its most conspicuous features are its enormous eyes, which occupy almost the whole head, its huge yolk sac covered with a fine network of bloodvessels leading to the heart, the beating of which can plainly be seen. Along the back is a strip of pigment extending from the head to the tip of the slender tail.

2. SWIMMING MOVEMENTS.

Although the Brook Trout spends most of the first six weeks of its larval life lying quietly on its side, it is perfectly capable of swimming as soon as the egg case is lost. In fact, Paton ('07), who worked on trout among other varieties

of fish, states that definite progression is possible when the embryo is nine or ten millimeters long. In the present experiments, if a fish which had just hatched was suddenly touched, it would whirl round and round as if its cumbersome yolk sac formed a movable pivot. By the fourth day the movements are still rotatory, but the fish swim in larger circles and can go straight ahead for a greater distance. There is also more darting about, the tail being always the most active part of the body. The trout which is one week old (14 - 15 millimeters) swims in a spiral course. As the yolk sac diminishes in size, the fish is better able to control its movements. It lies upon its ventral side like an adult at the age of six weeks in most cases, and in swimming, continually darts about, turning first one way, then the other.

3. REACTION TO MECHANICAL JARS.

Possibly the first stimulus to which a developing trout reacts is that of mechanical jars. Often before the embryo has completely left the shell, the shaking of the dish or currents in the water cause it to contract, and if the tail is free, to swim about with the head still encased. This sensitiveness to mechanical vibrations continue~~d~~s throughout the larval life. Even so slight a vibration as that caused by blowing on the water makes the fish dart about.

4. REACTIONS TO TOUCH.

The sense of touch is well developed when the trout hatches, but it is impossible to predict what response will be given to a stimulus in any particular part of the body. Embryos in nearly all stages of development from the time of hatching until the yolk sac was lost, were touched systematically with a slender, pointed stick, and with bristles to determine whether one part of the body was more sensitive than another. I found, as Paton ('07) did, that although it is very difficult to localize the tactile areas, the head is much less sensitive than the body, and the eye is quite insensitive. Judged by such responses, the tail seems to be the most sensitive part of the body. It was found that the trout avoided a brush much more vigorously than they did a pointed stick or a single bristle. This is probably because the brush stimulates them at more points.

If touched persistently, the embryos swim about, turning rapidly in all directions. When they are eventually fatigued, the responses become less marked; the trout may then merely move its tail or increase the rate of movement of its fins. It may even become absolutely quiet for a time, after which the reactions take place as before. The young trout show some measure of adaptability, for they grow somewhat accustomed to being handled, and particularly in the case of the oldest fish (three months old), those which had been repeatedly picked up were slightly easier to catch than those which had never been touched.

5. REACTIONS TO CURRENT.

Since Brook Trout live in swift flowing streams, one would expect them to react to currents. In order to test this matter, a trough was constructed in which they could be tested. The apparatus was fifty inches long by two and one-fourth inches wide and three inches deep with straight sides. A piece of tubing connecting with a faucet was attached to the center of one end, in such a way that a current of uniform intensity flowed through the whole length of the trough; at the other end, was an outlet covered with netting to prevent the loss of the fish.

After testing various strengths of current, the one which brought about the greatest number of reactions was found to be that which carried carmine solution the length of the trough in half a minute. Therefore, this strength of current was used in most of the experiments. Since all tests were made in a dark room, it was a simple matter to turn on the faucet a certain distance with the room in total darkness, in that way eliminating all reactions to light. Nevertheless since it was found that the daylight had little effect on the results, the room was not darkened for all the experiments.

Nearly all stages of young Brook Trout from the time of hatching to the absorption of the yolk sac were tested. Table I shows some of the results.

TABLE I.

Showing the Reactions of Brook Trout to Current.

Number of experiment	Number of fish used	Age of fish	Condition of light	Number of fish positive	Number of fish negative	Number of fish indifferent	Per cent of fish positive
1	25	4 days	day	22	0	3	88%
2	25	4 days	dark	21	0	4	84%
3	20	34 days	day	17	0	3	85%
4	20	42 days	day	16	0	4	80%

Total percentage of Brook Trout reacting positively 84.25%

The fish were placed in the trough one at a time in most cases with right and left sides alternately toward the current before the water was turned on. The fact that the older trout showed a slightly smaller percentage of positive reactions is probably not significant, as there appears to be no difference in their reactions, except such as would be caused by their greater activity and strength. Although it is not recorded in Table I, embryos which had just been hatched were found to react positively to current. But they were usually unable to swim more than a few centimeters, or able merely to orient themselves, owing to the size of the yolk sac.

While none of the Brook Trout were persistently negatively in their reactions to current, there were always a few which did not give a definite positive response. Since it was noted that

a fish was sometimes carried backward farther than it was able to advance, the four embryos in experiment number two which did not react definitely were tested later in the light, where they could be watched. One fish did not swim at all. Three fish were carried backward, but oriented toward the source of the current. They struggled to advance, but were unable to do so. Therefore, these were actually positive.

Of the twenty-one which are marked positive, five were evidently weak; their condition somewhat resembling the three just mentioned. Since these were found on being tested in the light to be clearly positive, and on the third trial in the dark progressed decidedly toward the current, they were included with the trout which had just been observed to move definitely against the current.

In order to discover whether surrounding objects effect the reaction to current, a striped paper was passed back and forth, beneath and at the sides of the glass dish containing Brook Trout about three weeks old. No reaction resulted. Brook Trout were also placed in a round glass dish set within another dish and a current of water made to run between the dishes. To this also the fish failed to react. Hence during the first few months, the sense of sight appears to have little or no relation to the reaction of Brook Trout to current. This does not agree with what Lyon ('04) believed to be true regarding the fishes with which he worked.

Positive rheotropism was also exhibited by a school of German Brown Trout two or three months old, that were almost invariably found resting or swimming about near the source of the current in the trough where they were kept. On testing Rainbow Trout three days old, when the yolk sac is enormously large, forty or fifty per cent were observed to be positive to current, while sixty per cent were indifferent, the latter either lying quiet or whirling about without orienting themselves when stimulated.

6. REACTIONS TO LIGHT.

That young Brook Trout are negatively phototropic has been recognized by the fish-hatchers who, finding that the trout seek the dark corners, keep the troughs covered. Their phototropism, however, was tested more accurately in the following manner: a Nernst lamp was placed within a large box (75 cm. wide x 120 cm. long x 120 cm. high) blackened inside and out, and having an opening (6 cm. x 9 cm.) at one end. A narrow glass dish 4 cm. through containing water was placed before the hole to absorb the heat rays; at right angles to this was an oblong glass dish with rectangular sides (38 cm. long x 10 cm. wide x 8 cm. high) in which the fish were placed.

Brook Trout of nearly every age, from those which had just hatched to those two months old, were placed in the dish singly or in groups and left for varying lengths of time. Table II shows the results.

TABLE II.

Showing the light reactions of Brook Trout.

Age of trout	Number of trout	Strength of light	Number of trout negative	Number of trout positive
2 days	25	1.5 candle meters	14	0
2 days	25	2.3 candle meters	21	2
2 days	5	7.7 candle meters	4	0
21 days	10	2.3 candle meters	7	2
21 days	10	7.7 candle meters	8	0
21 days	10	16 candle meters	8	2
Totals	85		62	6

Number of trout indifferent	Percent of trout negative	Percent of trout positive	Percent of trout indifferent
11	56%	0	44%
2	84%	8%	8%
1	80%	0	20%
1	70%	20%	10%
2	80%	0	20%
0	80%	20%	0
17 Totals	75%	8%	17%

In the experiments tabulated the trout were placed in the center of the dish with right and left sides alternately toward the light, so as to eliminate complication from a propensity to turn toward a particular side of the body. Each fish was observed for five minutes. The strengths of the lights given are approximately what the fish actually encountered in the center of the dish. It may be noted that a somewhat greater percentage reacted negatively to a light 2.3 candlemeters than to a light 1.5 candlemeters. Above 2.3 candlemeters, however, the increase in the strength of light seems to make little difference. Brook Trout less than a week old in general react more strongly to a weak light (2.3 candlemeters) than to a strong one (16 candlemeters). With the older fish this does not seem to be true.

The conclusion that young Brook Trout larvae are negatively phototropic was corroborated by other incidental observations. When a dish containing fish was placed before a window, they almost invariably sought the side of the dish away from the light. The same was true of the Rainbow Trout.

In order to discover whether a Brook Trout is photokinetic, a Nernst lamp was suspended about eighteen inches above a dish containing them. When the light was first turned on, the trout darted about vigorously, many seeking the corners of the dish. After a few minutes exposure,

however, they come to rest quietly as before. The same experiment was tried with Rainbow Trout with like results. It was observed that the raising of a window curtain suddenly allowing the sunlight to fall on a dish of Rainbow Trout, stimulated them to unusual activity for several minutes.

From these experiments it is evident that Brook Trout are photokinetic and negatively phototropic.

7. LIGHT AND CURRENT.

It has been shown that Brook Trout are negative to light and positive to current. It is desirable to know how they react when the two stimuli conflict. Fish-hatchers claim that when a light is placed at the head of the current, the trout go away from the light, thus reversing the usual reaction to current; in order to study this matter, the trough used for the current experiments was entirely covered except for an opening 3 cm. x 4 cm. at the end where the water entered. Opposite this opening, was placed a Nernst lamp having an intensity of about ten candlemeters in the center of the trough.

Trout about one week old were placed in the center of the trough, four at a time in most instances, since the trough was found to be large enough to hold that many without interference. Their positions were noted just before the water was turned on and again five minutes later. Twenty-five Brook Trout were used. Of these twenty-three moved away from the light and two fish did not change their positions.

This seems to show that Brook Trout become negative to current when a light is placed at the head of the stream. This probably means that in natural conditions, when they have to choose between shelter and cool water, they seek shelter.

8. CARBON DIOXIDE AND LIGHT.

Since an excess of Carbon Dioxide is a condition which a growing fish is likely to meet, the way in which a Brook Trout responds to it and the effect it has upon its light reactions is very important in determining whether or not the trout is to escape from the unfavorable conditions, and swim into ~~i~~ purer water, where there is more oxygen.

For the purpose of discovering the effect of an excess of carbon dioxide upon the response to light, fifty individuals were tested separately in the apparatus used for the light experiments in a five percent solution of carbonated water.*1 The strength of the light for one-half the fish was two candlemeters, for the other half about eight candlemeters. The results of the two were similar.

Almost immediately after a trout was placed in the carbonated water, the fins began to move more rapidly and the mouth to open and close with a gulping motion. Shelford ('14) describes this same condition in the fish that he tested in

---

*1. The solution of carbonated water was made by adding carbonated water from a siphon to the ordinary city water, which is taken from Lake Mendota.

an excess of carbon dioxide. In the present experiments, the trout were stimulated to great activity, swimming continually from one end of the dish to the other with no apparent reference to the light. They were as likely to stop at the end of the dish toward the light as at that away from it. Excess of carbon dioxide apparently causes the Brook Trout to be indifferent to light.

A ten percent solution of carbonated water was also tried, but this was found to partially anaesthetize the Brook Trout in from three to five minutes, and therefore no reactions resulted. The young trout were able to endure a five percent solution for two or three hours without apparent injury; at the end of such a period of time they seemed somewhat sluggish. A two and a half percent solution also had a stimulating effect. A twenty or twenty-five percent solution caused all swimming movements to stop almost immediately, and made the heart beat of a trout three weeks old fall within about eight minutes from an average of eighty beats a minute to thirty-seven. Death ensued very soon after that. This was tried in several other cases with similar results.

9. REACTION TO SHADOWS.

As was stated in the discussion of rheotropism, the Brook Trout three weeks old does not respond to moving objects outside the water. This seems to be true of objects in the water also, provided they do not cause mechanical jars. This

absence of reaction to shadows continues until the embryo is about six weeks old, when the greater part of the yolk sac is absorbed. At this time the trout suddenly begin to respond; the waving of a hand above the dish causes them to dart about in all directions. If such a movement is made repeatedly, however, they soon become accustomed to it and cease to react for a time.

The reaction to shadows is, therefore, not present at hatching, but becomes apparent at the time when the yolk sac is greatly reduced in size and shortly before the feeding reactions begin. It would be interesting to know whether there is a change in the eye or the nerve connections at this period, which brings about this new response, or whether it is merely due to increased swimming power.

10. FEEDING REACTIONS.

The feeding reactions begin when the Brook Trout are about two months old. At this time the larvae appear to develop a sudden curiosity concerning everything about them. They swim to the top more frequently and often explore the bottom.
The fish studied were fed liver chopped very fine and put into the water with a dropper. For several days the trout did not appear to notice it; at least they were not observed to eat it. A stream of meat juice directed against the body was avoided in the same manner as a jet of clean water. After a week or less, however, the trout began to take bits of food into their

mouths as they chanced upon them and often to swallow them. From this time on, they were observed to dart after pieces of meat floating about in the water, although they often rested directly upon meat lying on the bottom without appearing to pay any attention to it. They were also seen to chase bubbles and bits of filter paper, and to take them into their mouths, but they never swallowed them. The fish were fed in dishes with black or white bottoms. The trout were found to take food more eagerly from the dishes with black bottoms where the food was more plainly visible, although they would also eat pieces of meat over the white backgrounds. This fact is made use of by the fish-hatchers who feed the larvae in blackened troughs.

In order to discover what part is played by the chemical sense in helping the Brook Trout to find its food, a bag containing meat was placed in the water; this was nosed by the trout and one fish bit at it. At other times two bags, one with food and one without it, were set in the dish. The trout investigated both bags, but they bit at neither. They were apparently unable to discover meat hidden under a paper in the bottom of the dish. Although they wandered over it as they swam about, it was not noted that its presence had any effect upon the fish.

The Brook Trout apparently first react through sight to the presence of food, since they were often observed to leave pieces of meat near them to dart after bits farther away,

which would not be the case, were it the chemical sense which was most strongly stimulated. The gustatory sense appears to determine whether or not the food is swallowed.

C. GENERAL DESCRIPTION OF THE EARLY LIFE OF THE BROOK TROUT.

Let us follow a developing Brook Trout on the pebbly bottom of a swift flowing stream. During the first six weeks of its existence it does not move far from the spot where it was hatched, but lies quietly in the shadows among the stones, out of sight of its enemies. It is not affected by objects passing over head. If someone throws a stone into the water, the jar startles the little fish into swimming about rapidly for a few seconds, after which it sinks again into some shady nook. Here it rests, until a sudden eddy caused by an animal swimming through the water, makes it dart a few inches into the current. Other tiny fish touch and jostle it continually. If the water becomes filled with carbon dioxide, it becomes more active, and overcoming its impulse to avoid the light, swims about restlessly from place to place until it comes into purer water, where it again sinks down beneath the stones. Thus far its responses have been largely avoiding reactions, serving to keep it from unfavorable conditions.

When the trout is about six weeks old, it becomes more sensitive to objects outside itself. The sight of other animals passing by sends it scurrying under the cover of moss and stones. Shortly after this, it begins to be curious,

nosing nearly every object which it sees. It swims to the top of the water in pursuit of a bubble. It explores the bottom of the stream, often swimming head downward, passing in and out among the rocks, stones, and algae. Many particles on the bottom or floating above are taken into the mouth. If found to be good to eat, they are swallowed; if not, they are expelled. As the fish eats, it takes food more and more eagerly until it is satisfied, when it ceases to react, and hides in the algae.

Throughout its larval life the Brook Trout is reacting to external and internal stimuli, responding to nearly every current, object, or ray of light that strikes it.

In general, the behavior suits the needs of the fish. As long as the trout are very young, and are encumbered with the large yolk sac, which renders them unable to swim any distance, their reactions are such as would naturally tend to keep them lying quietly out of the sight of their enemies. They exhibit no curiosity, but avoid the light, hiding beneath the rocks and stones, reacting to current just enough to keep them from being carried down stream. The trout appear not to notice external objects, except as their approach jars the fish, making them struggle to regain their equilibrium.

As was previously stated, an excess of carbon dioxide renders them temporarily indifferent to light, so that they swim about restlessly until they reach a place where the water is purer.

When the Brook Trout grow larger, lose the yolk sac, and

become strong enough to escape their enemies by swimming away, they begin to notice moving objects inside and outside of the water. The approach of any object sends them darting about in all directions in search of a hiding place. Just before the trout are old enough to commence eating, they show great interest in every object in the water, and begin to try taking any small object from a bubble or a bit of alga to a piece of meat into their mouths, though they appear to swallow only such as are edible.

From the consideration of the facts of behavior, one is naturally led to ask what are the artificial conditions which best suit the needs and instincts of the young trout. In other words, what is the economic importance of the experiments discussed in this paper. One easily concludes from the observation of the natural conditions of Brook Trout and their reactions to current and carbon dioxide, that the first essential is cool running water with plenty of oxygen. The water should be free from algae of a sort which is apt to get into the gills.. If a fungus attacks the young trout, the disease spreads rapidly, unless the infected and dead fish are removed, since the fish knock against each other as they swim about.

The fact that Brook Trout are so strongly negative to light seems to indicate that hatching troughs should be covered,

or if the fish are in ponds or streams, that the trout should have natural covers, such as rocks, stones, or water plants, under which to hide. By living beneath these they may often escape predaceous animals which prey upon them.

Since it requires nearly a week for Brook Trout to learn to eat, they should be carefully watched when they are near the feeding stage, for if they do not learn to take food before the yolk sac is entirely absorbed, they will die of starvation. Shortly before the trout are two months old, they commence to swim to the top frequently and to exhibit curiosity, which indicates that they will soon begin to eat. Meat ground or chopped very fine should then be introduced into the water, so that the fish may take particles of it into their mouths by chance.as they wander about, and thus become accustomed to it before it is necessary for them to eat.

D. SUMMARY.

1. The Brook Trout which has just hatched swims with a whirling movement. About the fourth day after hatching, the trout commences to swim in a spiral course, and from then on, the movements become gradually better coordinated, the trout swimming in larger circles and going straight ahead for greater distances.

2. The Brook Trout reacts to touch and mechanical jars immediately after hatching. The head is the least sensitive to touch of any part of the body, the eye being insensitive.

The reaction is more marked when the trout is stimulated at a number of points, than when it is touched with a single bristle.

3. Positive rheotropism becomes apparent as soon as the trout has hatched.

4. The Brook Trout is photokinetic and negatively phototactic.

5. Directive light from a lamp at the source of the current reverses the usual rheotropic reaction, showing that Brook Trout are more strongly negative to light than they are positive to current.

6. An excess of carbon dioxide up to a certain point stimulates Brook Trout; a very strong solution depresses them. A five percent solution stimulates trout to move about continually and makes them indifferent to light. Stimulation is also brought about by a two and a half percent solution. A twenty or twenty-five percent solution causes a rapid fall in the rate of the heart beat, then death.

7. Brook Trout begin to respond to shadows about the sixth week after hatching, when the yolk sac is greatly diminished in size.

8. Feeding reactions commence when Brook Trout are about two months old. The sense of sight seems to cause the trout to take small objects into the mouth, the gustatory sense to decide whether or not they are edible.

9. Before the yolk sac is absorbed the reactions of the young trout are protective, afterward they are exploratory and aggressive.

BIBLIOGRAPHY.

Bernoulli, A. L.
1910. Zur Frage des Hörvermögens der Fische. Arch. f. d. ges. Physiol. Vol. 134, pp. 633-644.

Clark, Frank N.
1900. The Brook Trout. U. S. Com. of Fish and fisheries. Revised Edition. pp. 80-90.

Herrick, C. J.
1902. The Organ and Sense of Taste in Fishes. U. S. Commission Bulletin for 1902, pp. 237-272.

Lyon, E. P.
1904. On Rheotropism I Rheotropism in Fishes. Am. Jour. Physiol., Vol. 12, pp. 149-170.

Parker, G. H.
1909. Influence of the Eyes, Ears, and other Allied Sense Organs on the Movements of the Dogfish Mustelus canis (Mitchill). Bull. U. S. Fisheries; Vol. 29, pp. 45-47.
1910. Olfactory Reactions in Fishes. Jour. Exper. Zool. Vol. 8, No. 4, pp. 535-542.

Paton, S. 1907. The Reaction of the Vertebrate Embryo to Stimulation and the Associated Changes in the Nervous System. Mitteil. a. d. zool. Stat. z. Neapel, Bd. 18, Heft 2 und 3, pp. 535-581, Taf. 23-25.

Shelford, V. E. and Allee, W. C.
1914. Rapid Modification of the Behavior of Fishes by contact with Modified Water. Jour. Animal Behav., Vol. 4, No. 1, pp. 1-30.

APPROVED BY

A. S. Pearse

89089008163

B89089008163A

89089008163

b89089008163a

Google